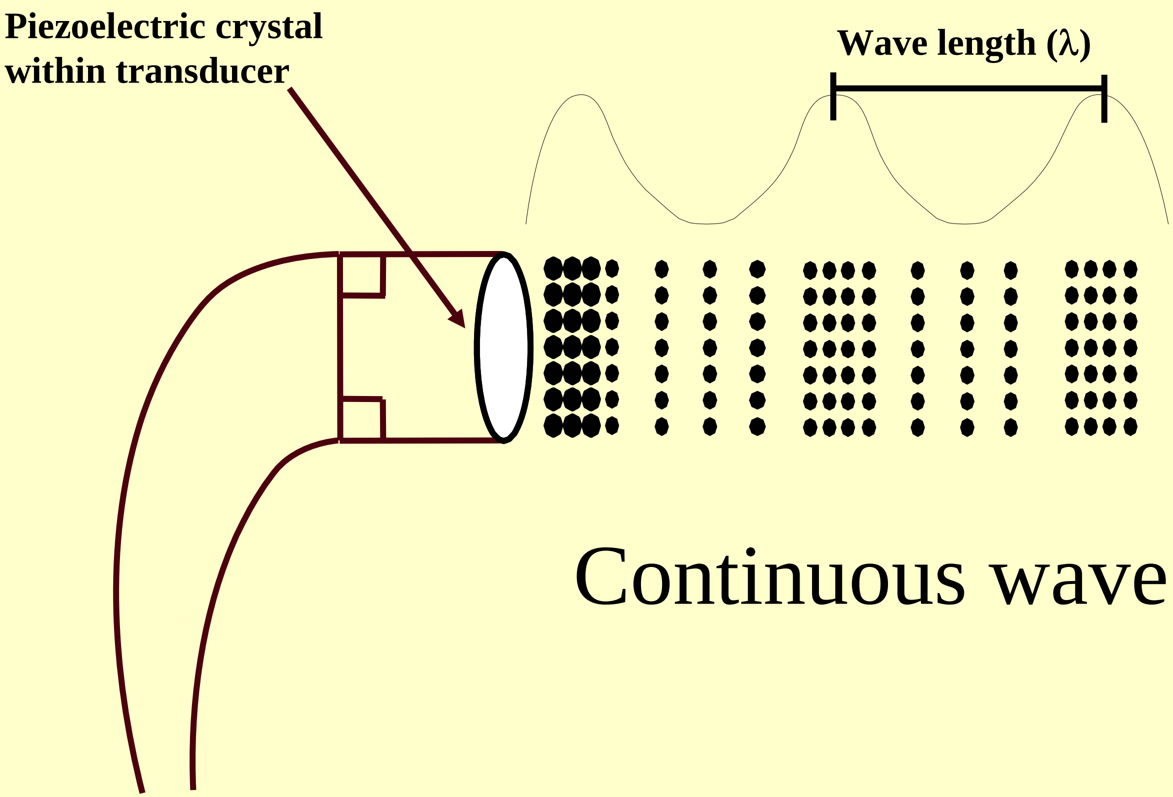
Biomedical Imaging - Historic Overview

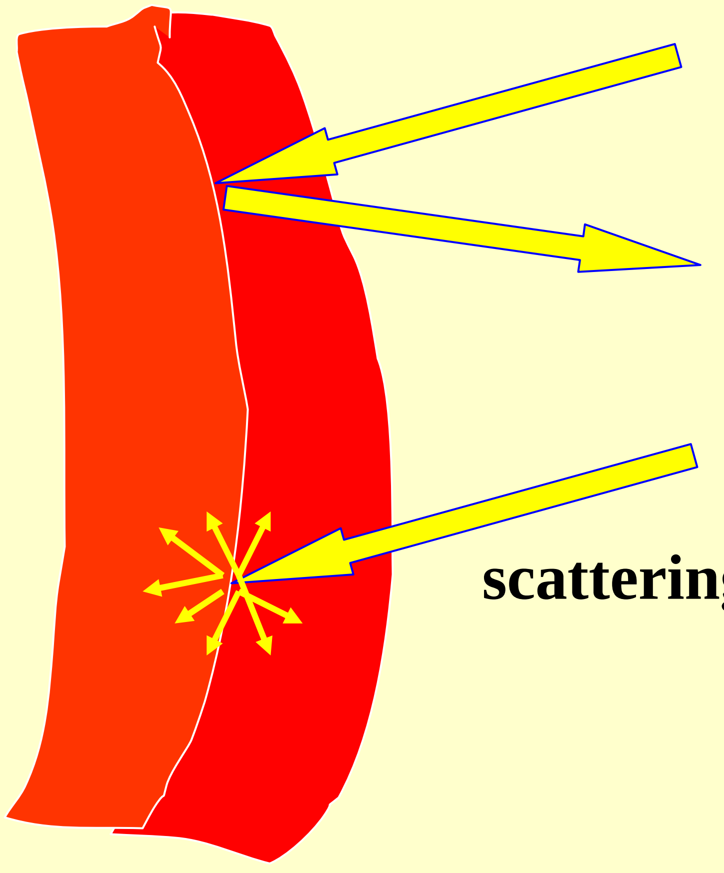
Method	Year of Discovery	Discoverer / Inventor	Wavelength / Energy	Basic Principles
X-ray imaging	November 8, 1895 (1896 first clinical use) 1918 Pneumo-Encephalography 1927 Cerebral angiography	Röntgen (NP Phys.1901) Pupin (Columbia) W. Dandy E. Moniz	electromagnetic wave l =10^{-12} to 10^{-9} m, 100eV-200KeV (ionizing radiation)	Opacity caused by Calcium in bones Photoelectric Effect~Z^3 Compton Effect
Computerized Axial Tomography (CAT-Scan)	(1917 math. foundation) 1972	(J. Radon-Astronomer) H. Hounsfield (EMI) British, Knighted, NP Med. 1979)	same as X-rays	Fourier filtered backprojection
Positron Emission Tomography	1953	Brownell, Sweet	electromag. wave l ~ 10^{-15} m 500KeV-2MeV (ionizing radiation)	positron pairs emitted in opposite direction
Single Photon Emission Computerized Tomography	1963	Kuhl, Edwards	electromag. wave l ~ 10^{-12} to 10^{-15} m 100KeV-500KeV (ionizing radiation)	photons emitted
Magnetic Resonance Imaging (MRI)	1946 Physics of NMR 1952 Spin Echo 1971, 1977 1973 since 1990 fMRI	Bloch, Purcell, Hahn R. Damadian (SUNY-DMC, idea for tissue 1971, whole body image 1977) P.C. Lauterburg (first clinical image of finger)	non-ionizing l ~ 1 to 10^{-5} m,1 MHz to 1GHz	Nuclear Spin (relaxation depends on environment)
Ultrasound	1952 1961	Wild, Reid First clinical use	Soundwaves l ~ 2 to 10^{-2} m, ~ 1MHz	Different speed of sound in diff. tissues
Magneto Encephalograpgy (MEG)	1984	M. Singh, R. Brechner, V.W. Henderson		changes in magnetic field due to electrical currents in brains
Diffuse Optical Tomography (DOT)	1992	Barbour (SUNY-DMC) Chance (UPENN)	l = 700-900nm (non-ionizing)	interaction of light and tissue

Ultrasound Imaging (US)

Ultrasound: Generation



Ultrasounds: principle



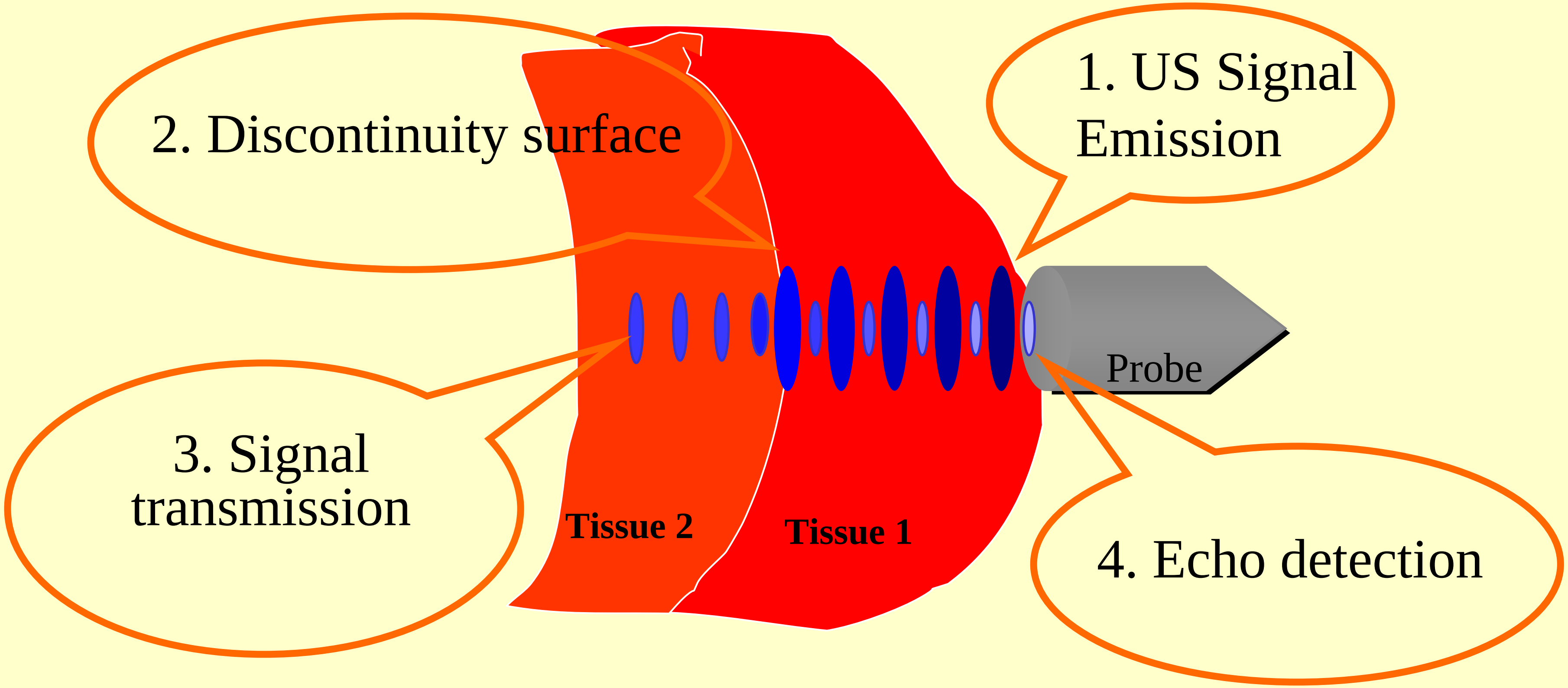
Specular (vessels, cardiac cavity, epicardium)

scattering (capillars, myocardial fiber

Ultrasound Imaging

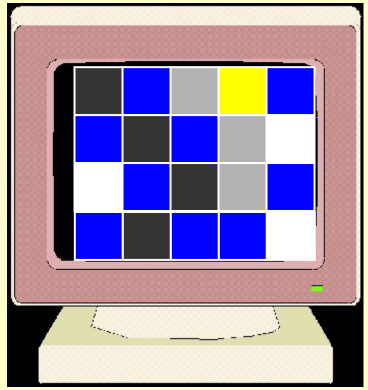
ECHO IMAGE GENERATION

US imaging is based on the detection of echoes due to discontinuities in the tissue or among tissues

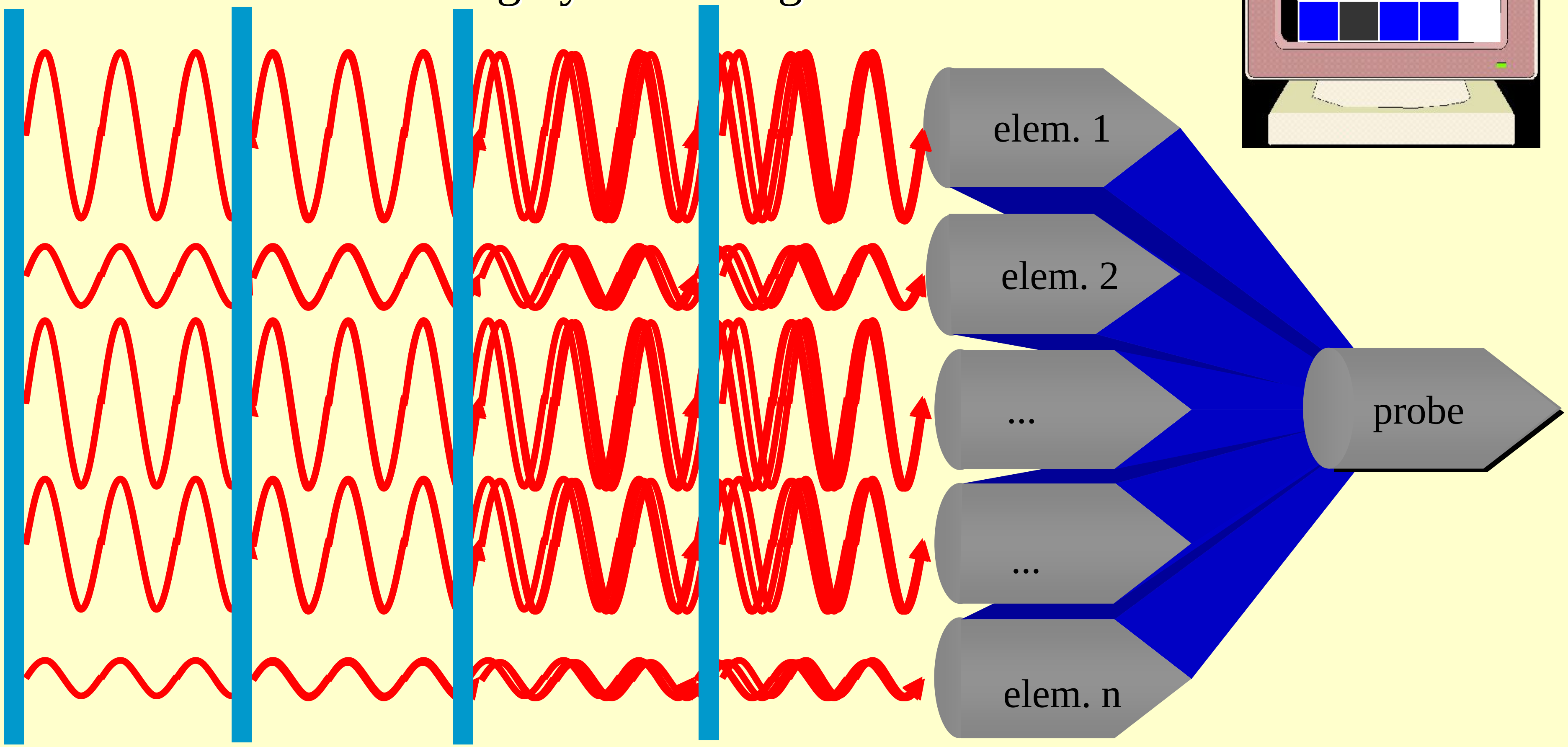


Ultrasound Imaging

ECHO IMAGE GENERATION

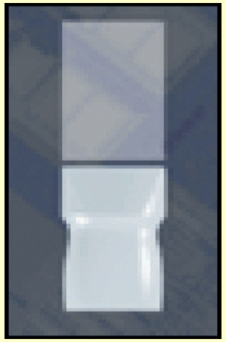


Transducer measures echo-signal amplitude (depending on tissue characteristics) that ultimately affects gray level image

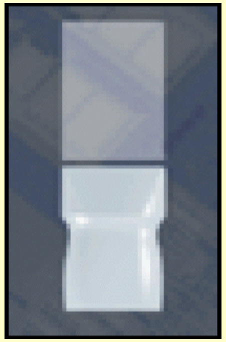


Linear Array

5.0 MHz



7.5 MHz



Anular Array

APA 2.5 MHz

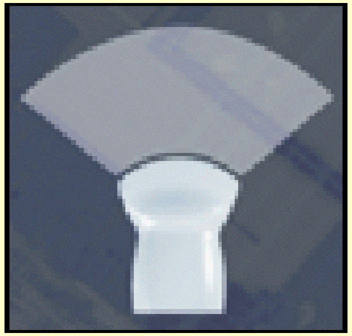
APA 3.25 MHz

APA 5.0 MHz

APA 7.5 MHz

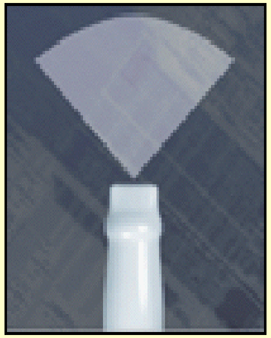
Curved Linear Array

5.0 MHz & 3.5 MHz

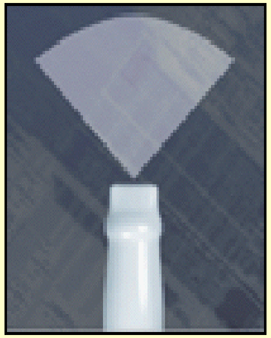


Phased Array

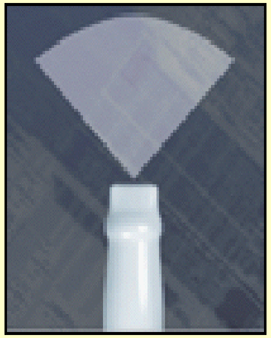
2.5 MHz



3.5 MHz



5.0 MHz



TEE Multiplane probes

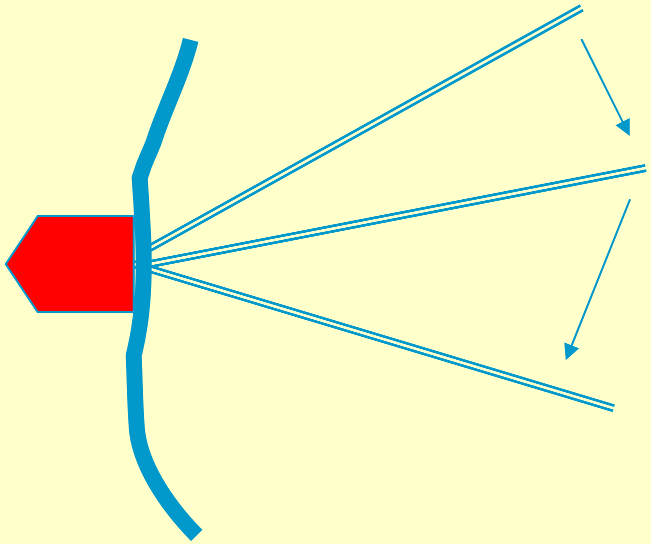
MPTE 5.0 MHz

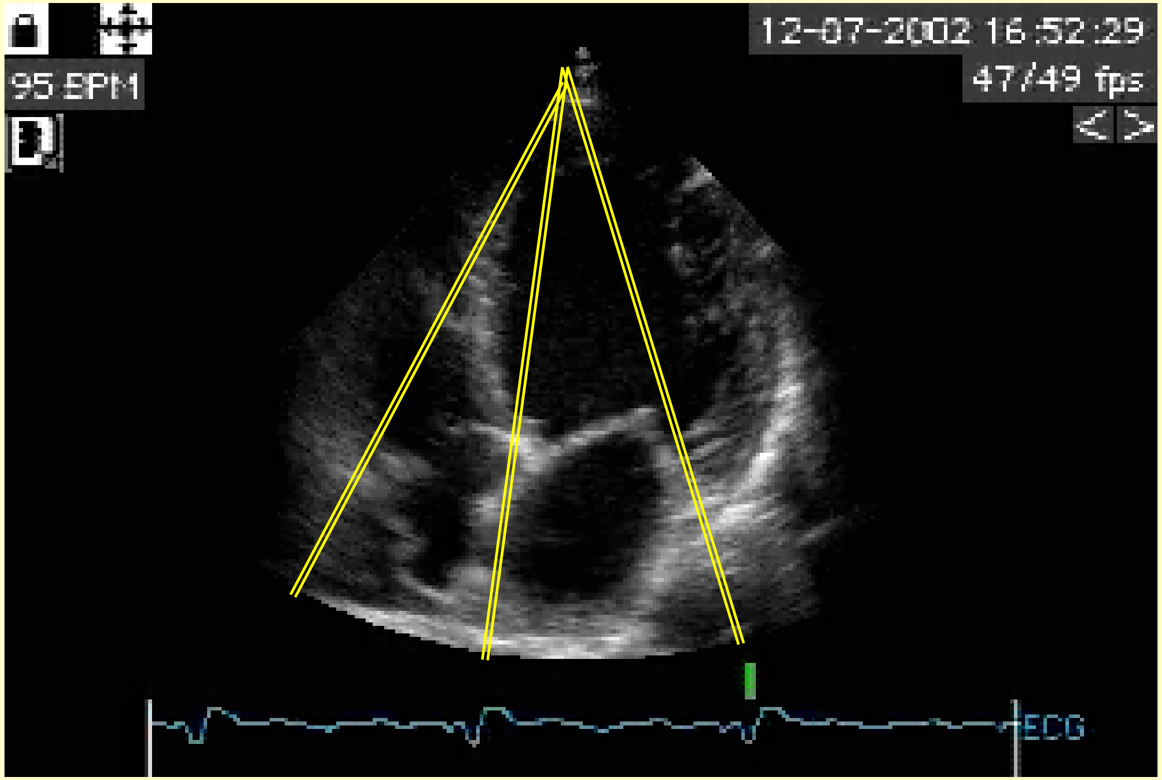
AMPTE 5.0 MHz

PMPTE 6.0 MHz

Any Probe Operates in Multifrequency Mode

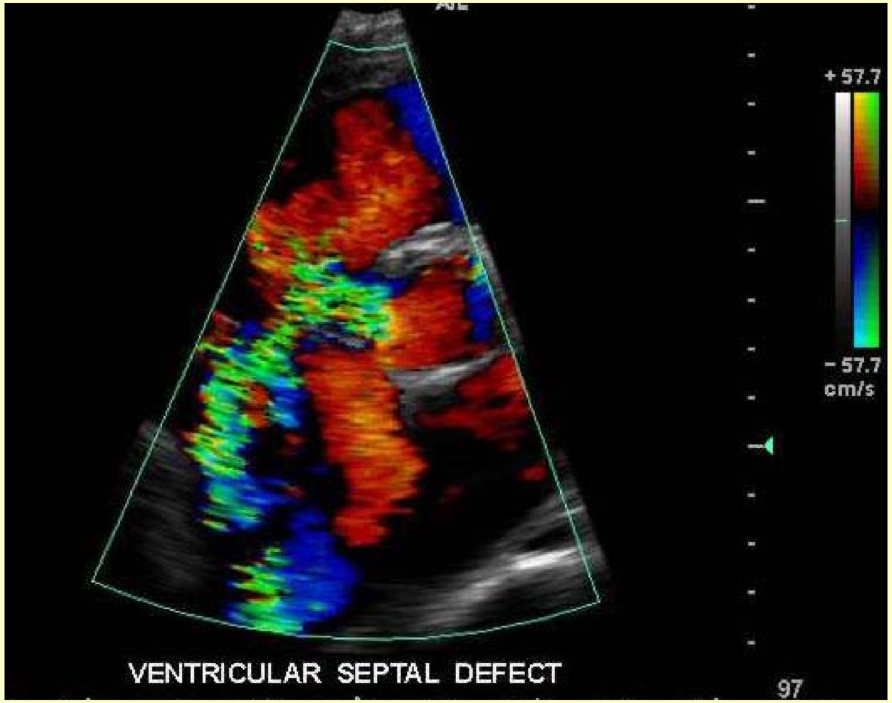
US: Image formation

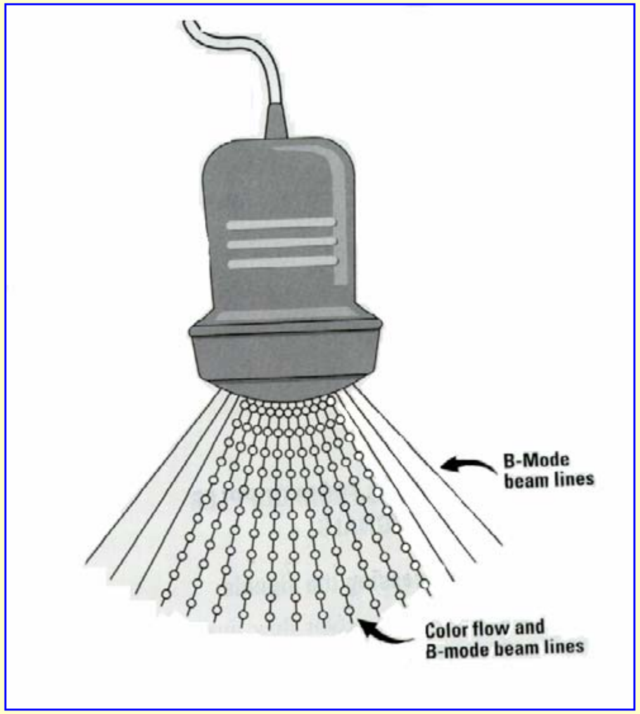




During beam steering a region of tissue is irradiated by ultrasound energy.
At any acoustic discontinuity in the tissue a backscattered signal is generated, processed and represented in a gray scale monitor

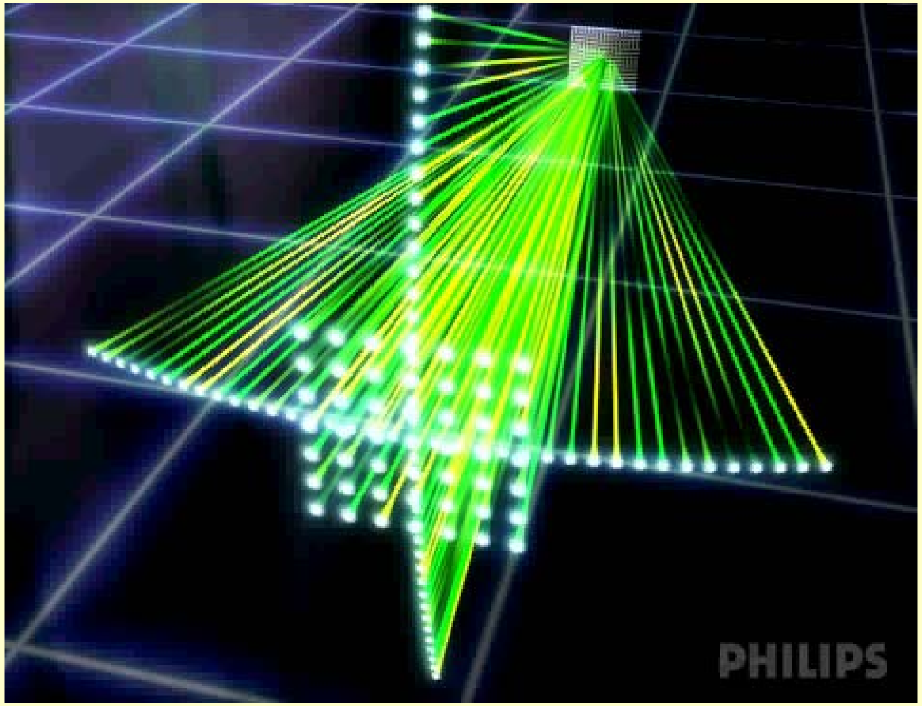
Color doppler

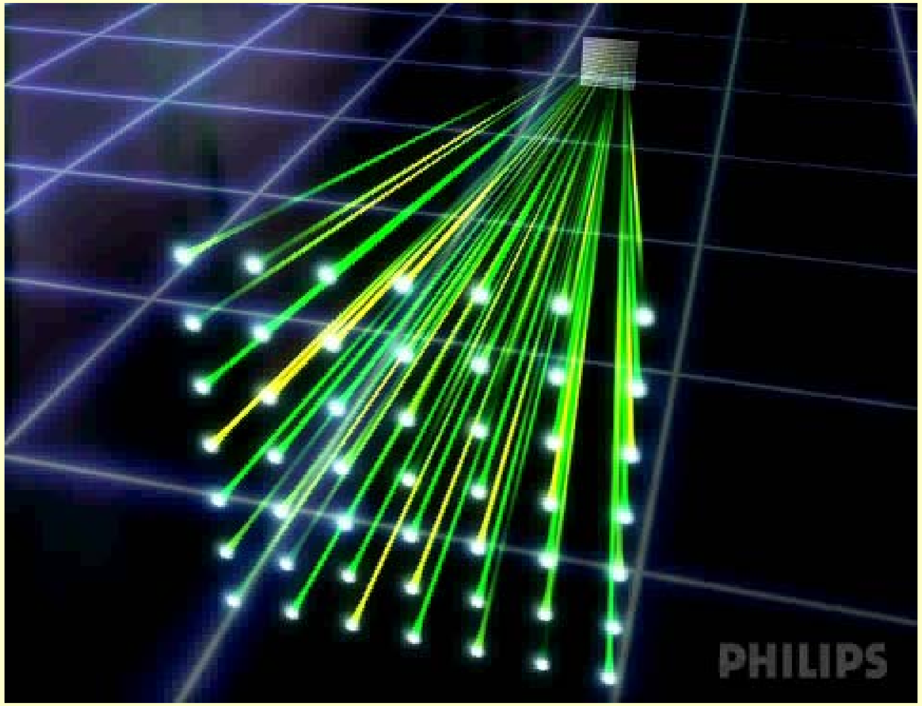




3D Ultrasound Imaging

3D probe





Ultrasound Imaging

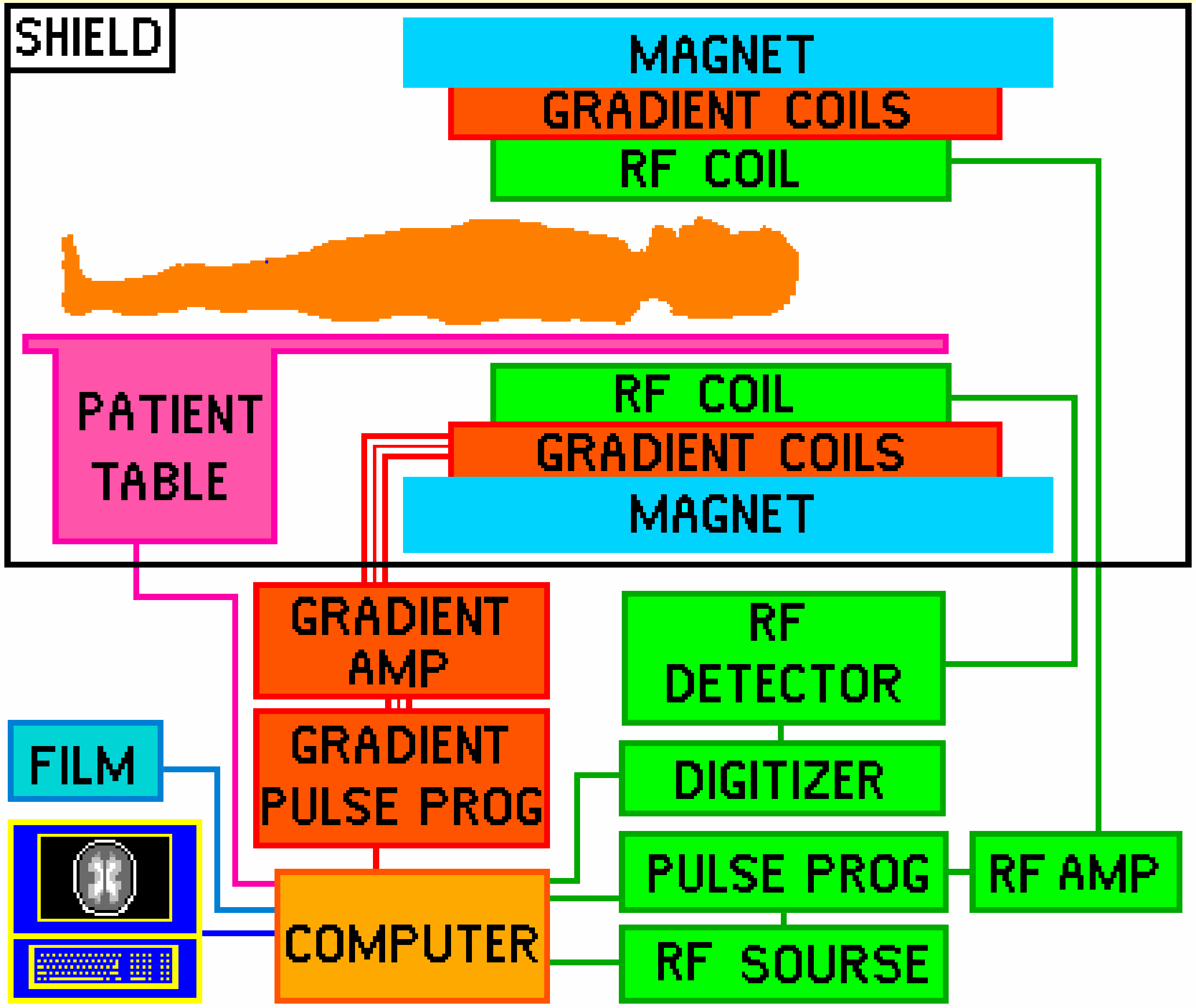
Foetus 3D Ultrasound Imaging

Ultrasound Imaging

- Ecography exploits vibrational energy in the frequency range of 1.5 to 50 MHz,
- Peculiarities:
  - non-ionizing
  - High spatial and temporal resolution
  - Riskless for patient
  - Low cost

Magnetic Resonance Imaging (MRI)

MR: Hardware


SHIELD
MAGNET
GRADIENT COILS
RF COIL
PATIENT TABLE
RF COIL
GRADIENT COILS
MAGNET
GRADIENT AMP
RF DETECTOR
GRADIENT PULSE PROG
DIGITIZER
FILM
PULSE PROG
RF AMP
COMPUTER
RF SOURSE

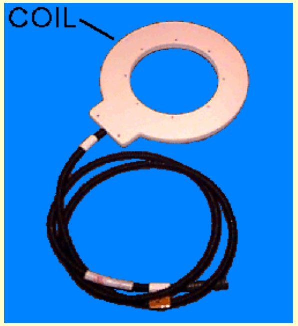
MR: Hardware

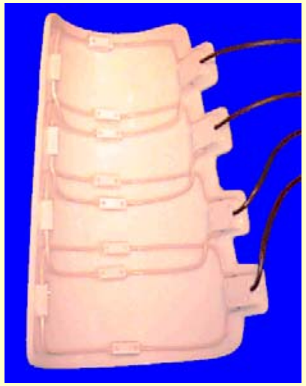
RF coils generate the Rf pulse and detect the MR signal

"Body coil"

"Brain coil"

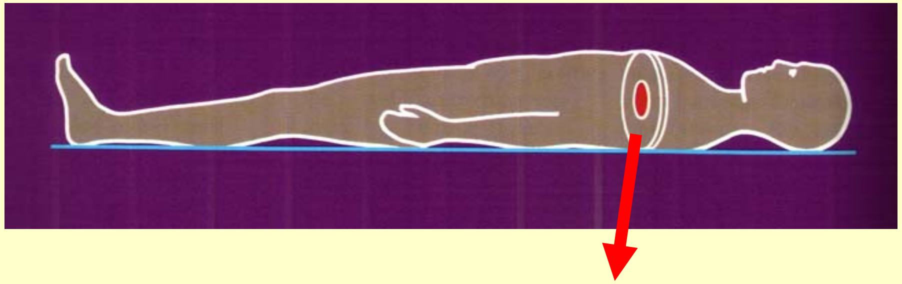
"single coil"

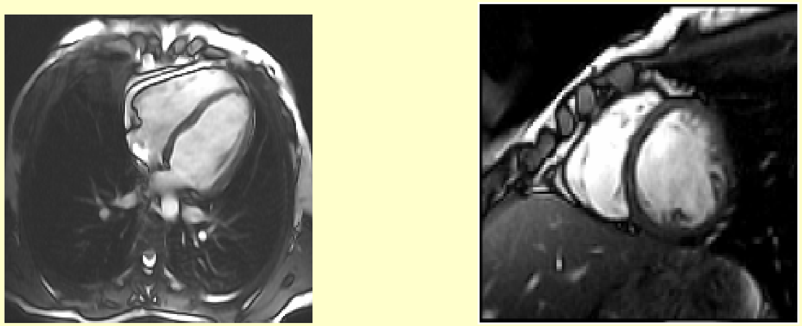


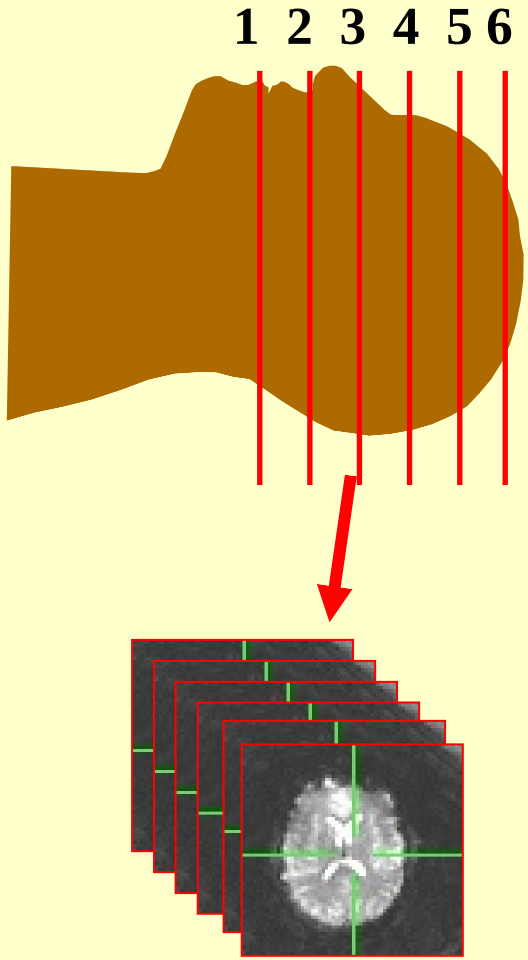


"phased array coil"

MRI - Acquisition

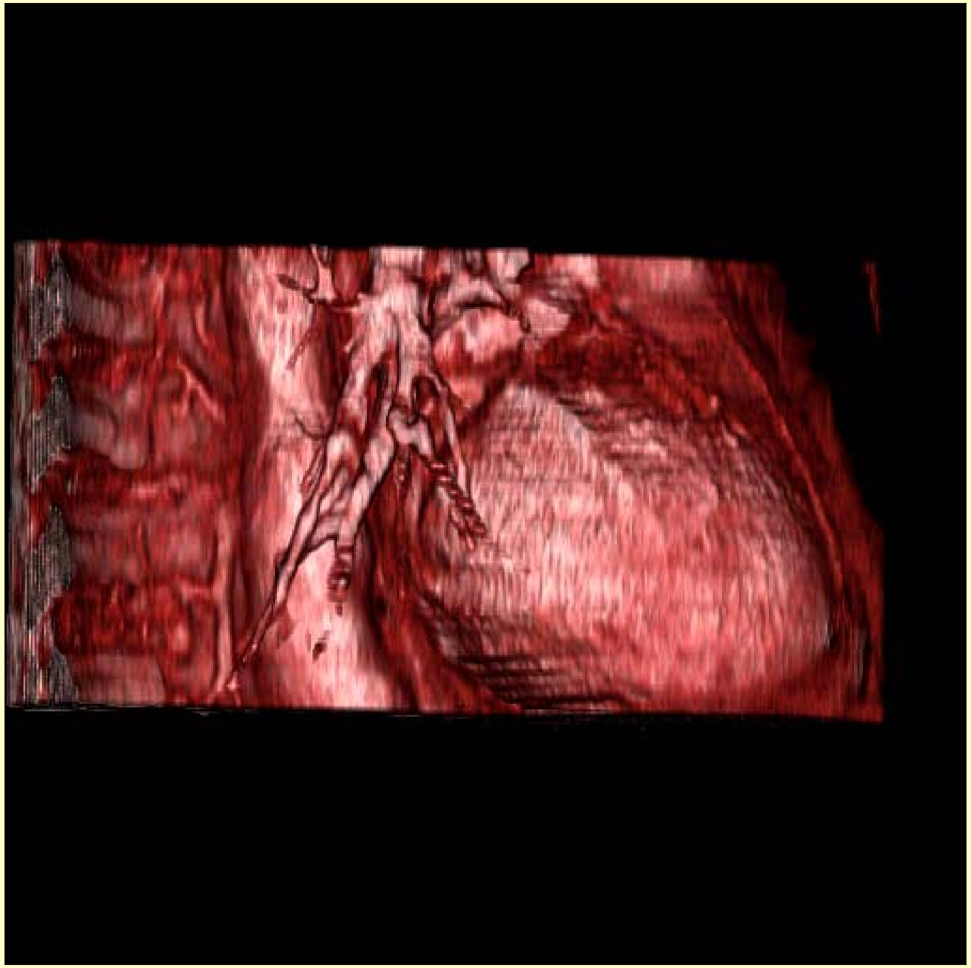




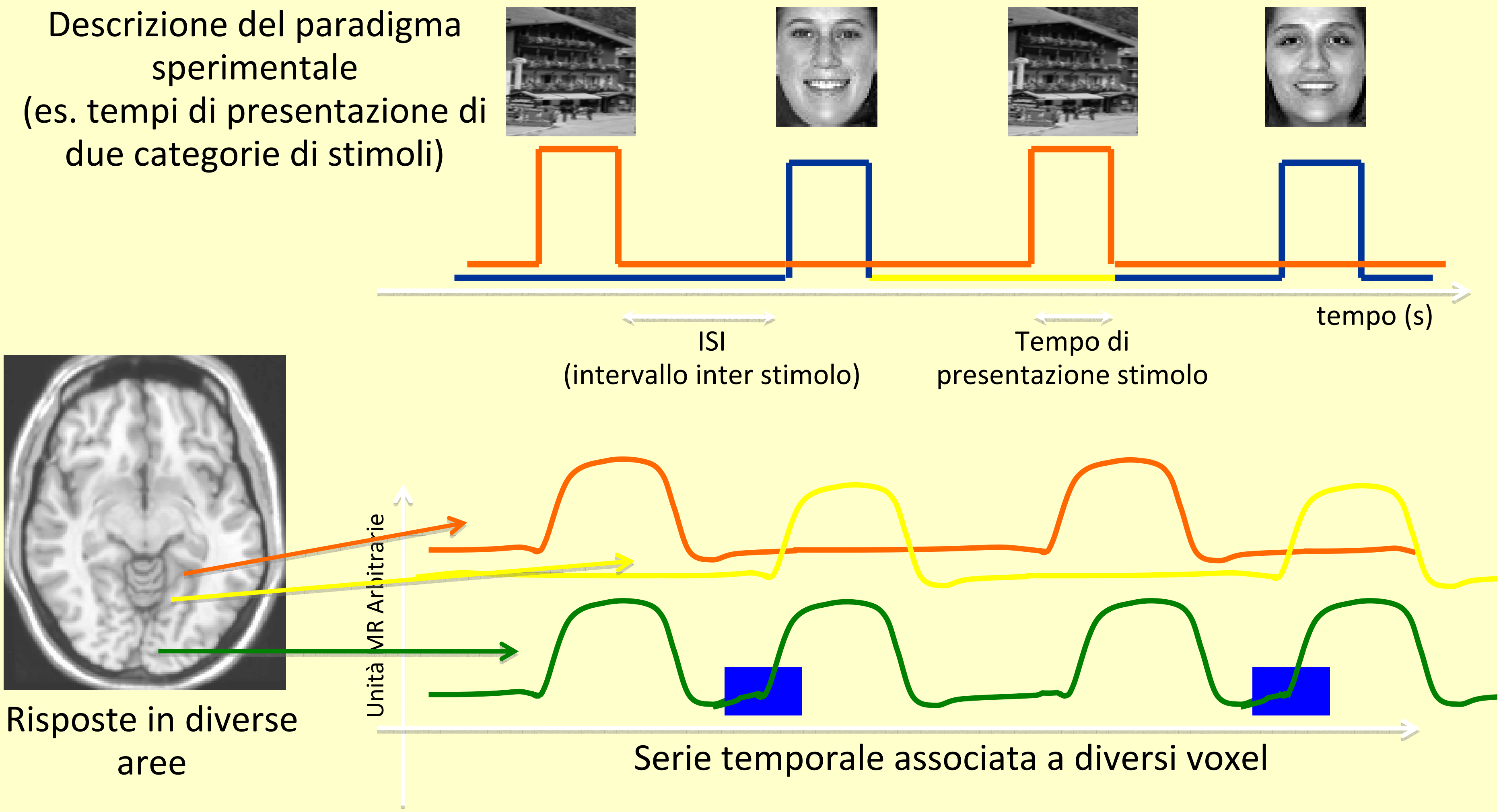


Magnetic Resonance Imaging

3D Cardiovascular Reconstruction

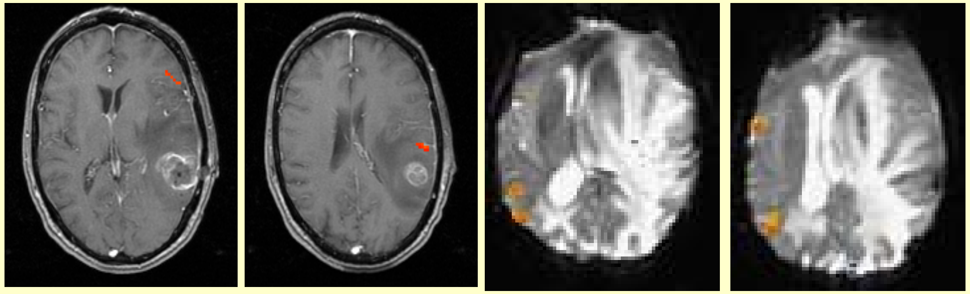


Il paradigma sperimentale



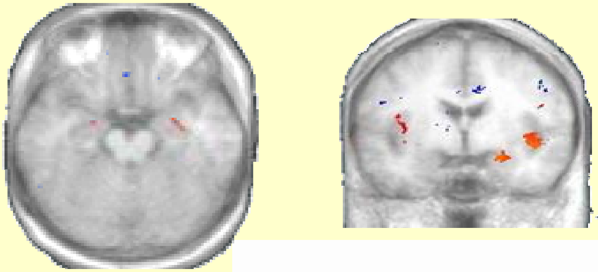
Applicazioni

Planning prechirurgico

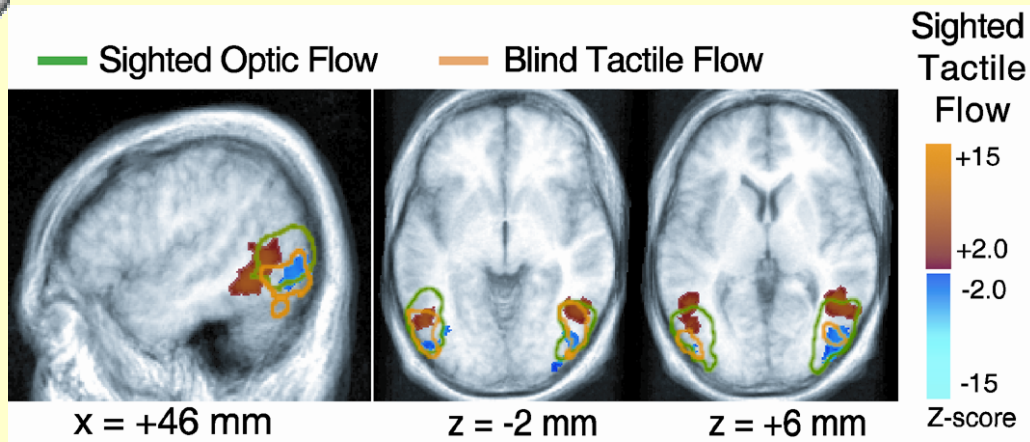


Psichiatria

i.e. Fobia sociale



Studio delle funzioni sensori/motorie cognitive



The Effect of Visual Experience on the Development of Functional Architecture in hMT+

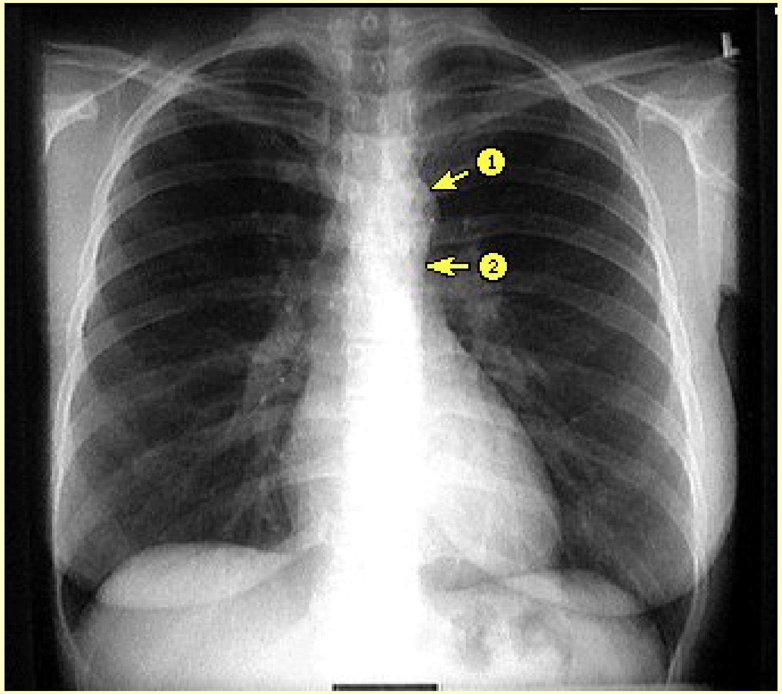
- Tharin S, Golby A. Neurosurgery. 2007;60(4 Suppl 2):185-201
- C. Gentili et al Brain Research Bulletin, 77, Issue 5, 25 November 2008, Pages 286-292, 2008
- E. Ricciardi et al Cerebral Cortex. Advance Access published March 19, 2007. doi:10.1093/cercor/bhm01840)

X-Ray Imaging (XR)

Conventional XR

Digital XR

Portable XR

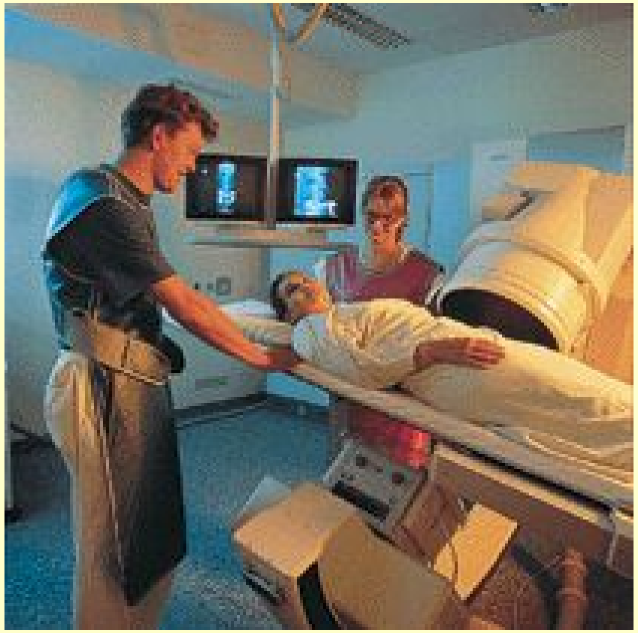


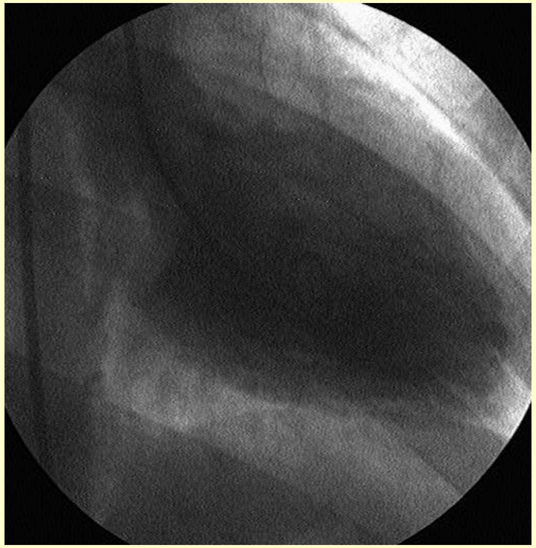
XR: Examples

Digital XR

Portable XR

Angiography with subtraction of background image

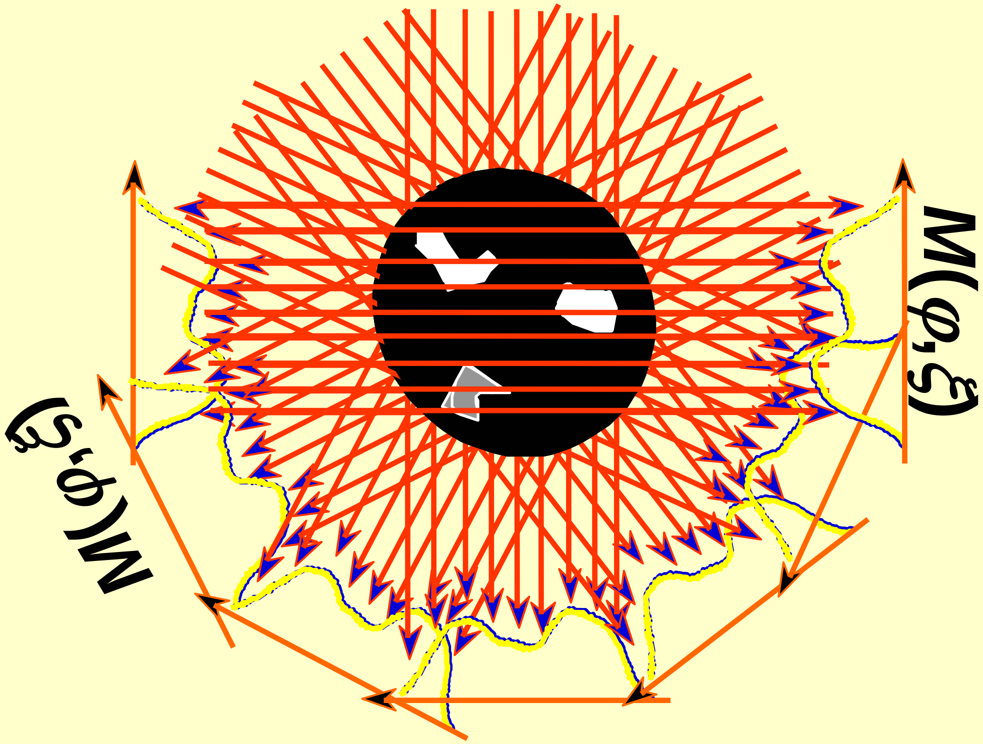




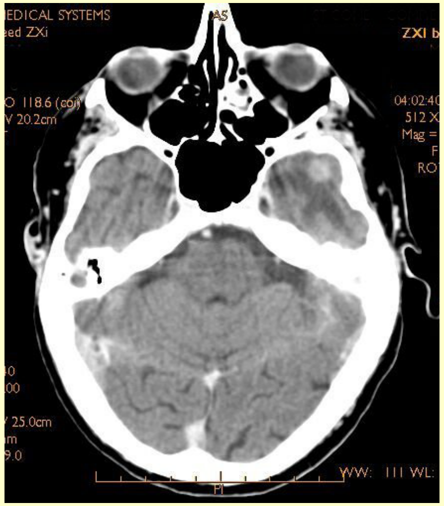
- XR angiography
  - Monoplane
  - Biplane
  - Multi-angle

Computerized Tomography (CT) Imaging

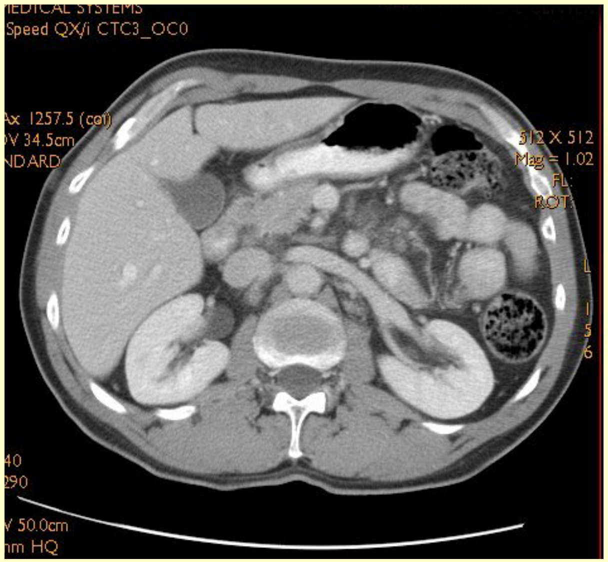
CT: Computerized Tomography

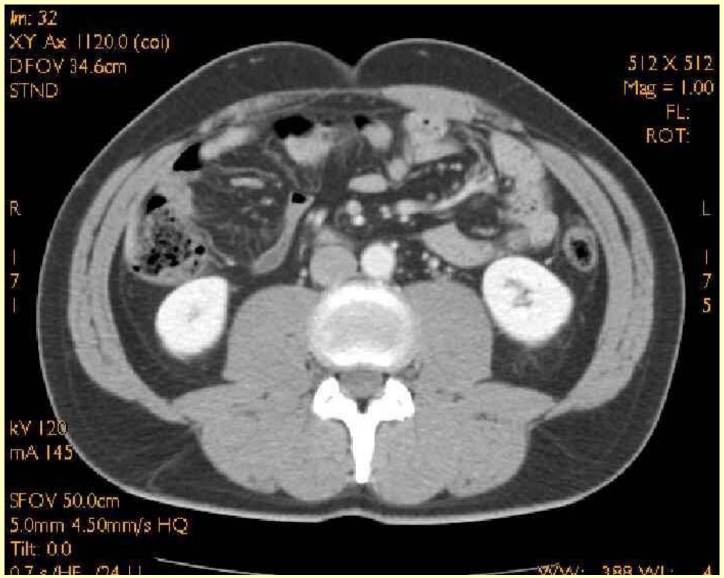


CT: Example


EDICAL SYSTEMS
eed ZXi
ZXI b
O 118.6 (coi)
V 20.2cm
04:02:40
512 X
Mag =
RO
V 25.0cm
WW: 111 WL:

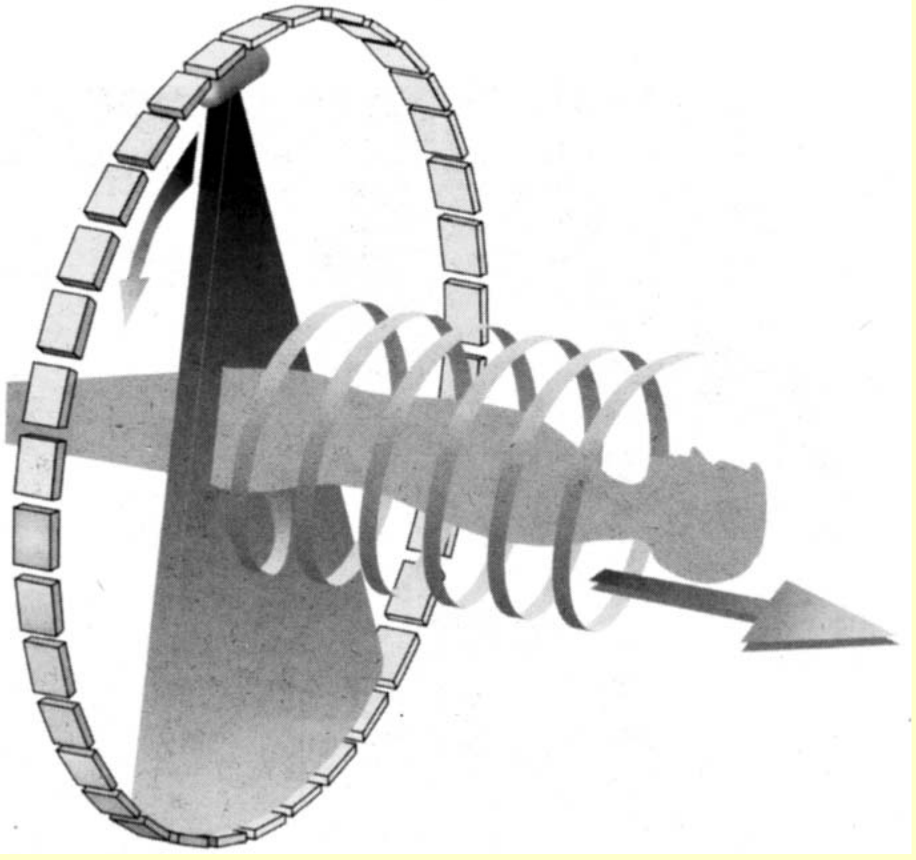

70.1 (coi)
0cm
0cm


EDICAL SYSTEMS
Speed QX/i CTC3_OC0
Ax 1257.5 (coi)
V 34.5cm
NDARD
512 X 512
Mag = 1.02
FL:
ROT:
40
290
V 50.0cm
mm HQ


Im: 32
XY Ax 1120.0 (coi)
DFOV 34.6cm
STND
512 X 512
Mag = 1.00
FL:
ROT:
R
L
kV 120
mA 145
SFOV 50.0cm
5.0mm 4.50mm/s HQ
Tilt: 0.0

CT: Hardware

Spiral CT

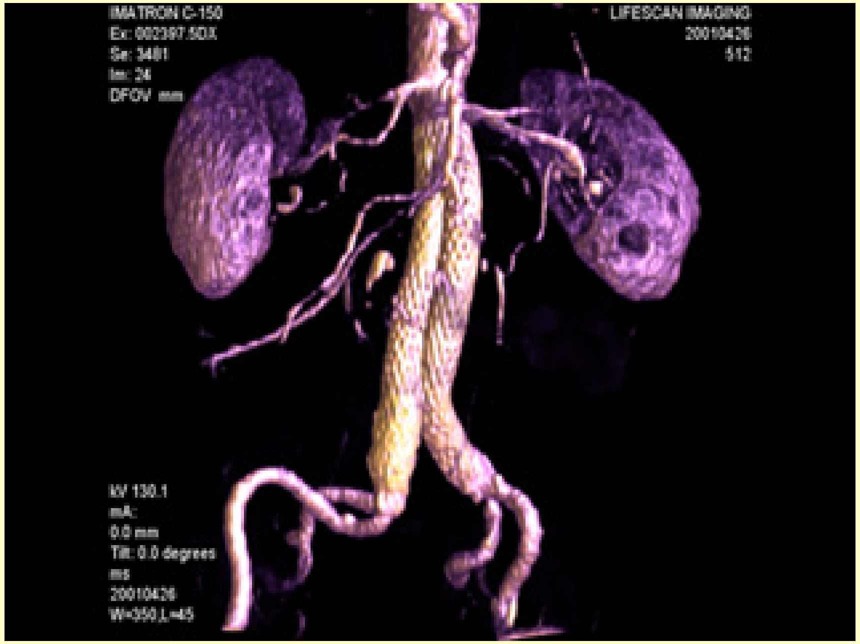


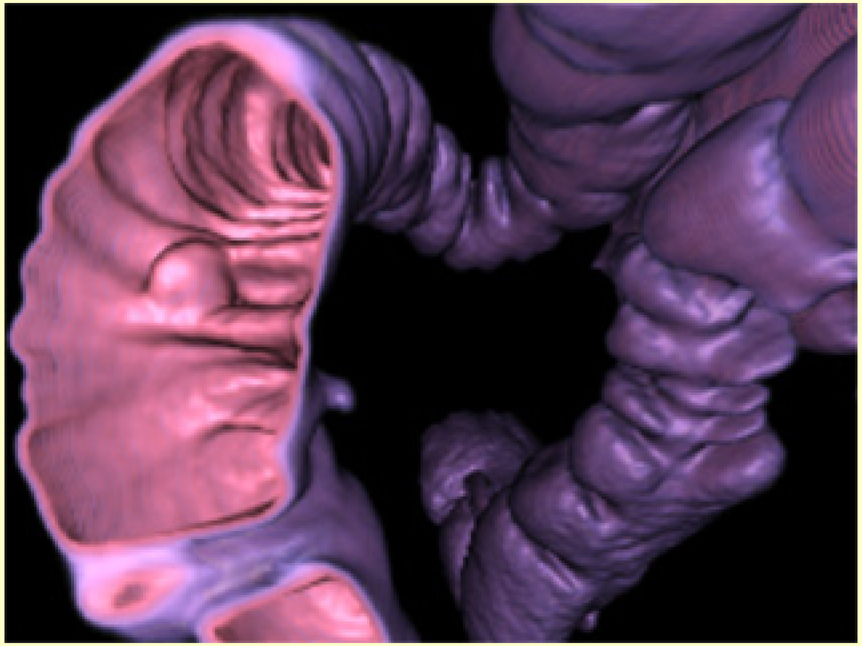
- Continuous linear movement of the bed during scanning

CT: Applications

3D Visualization

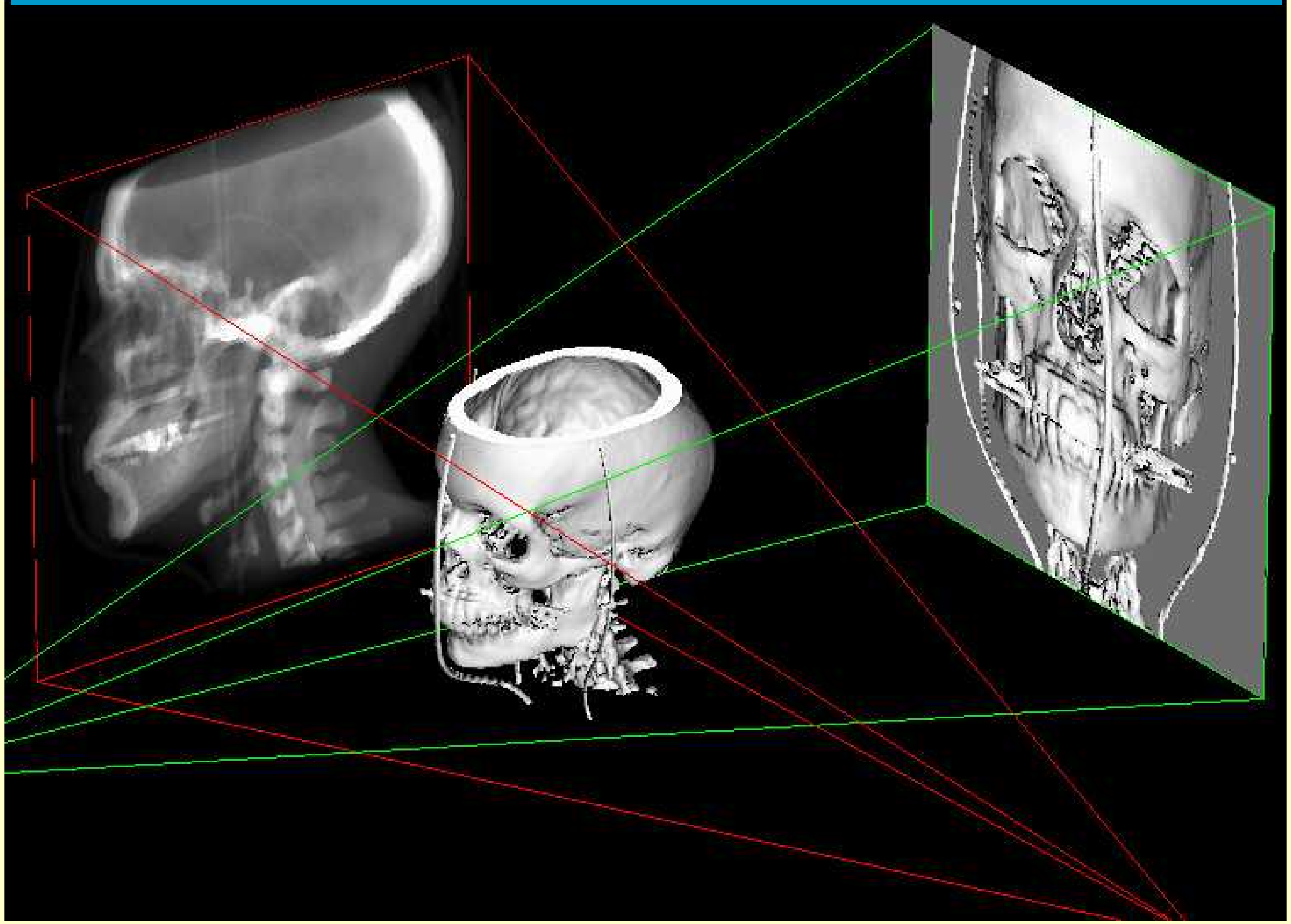
- Aortic Stent
- Colon (7mm polipus)





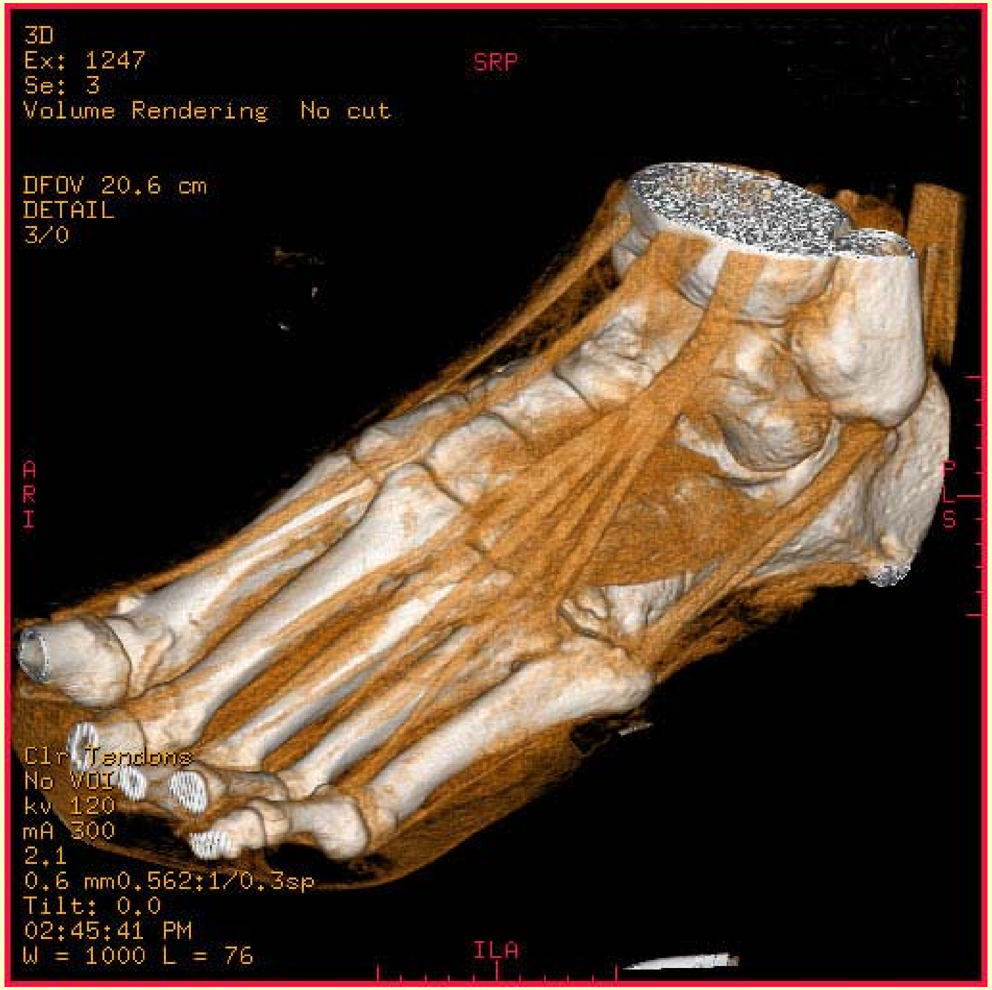
CT: Applications

3D Visualization



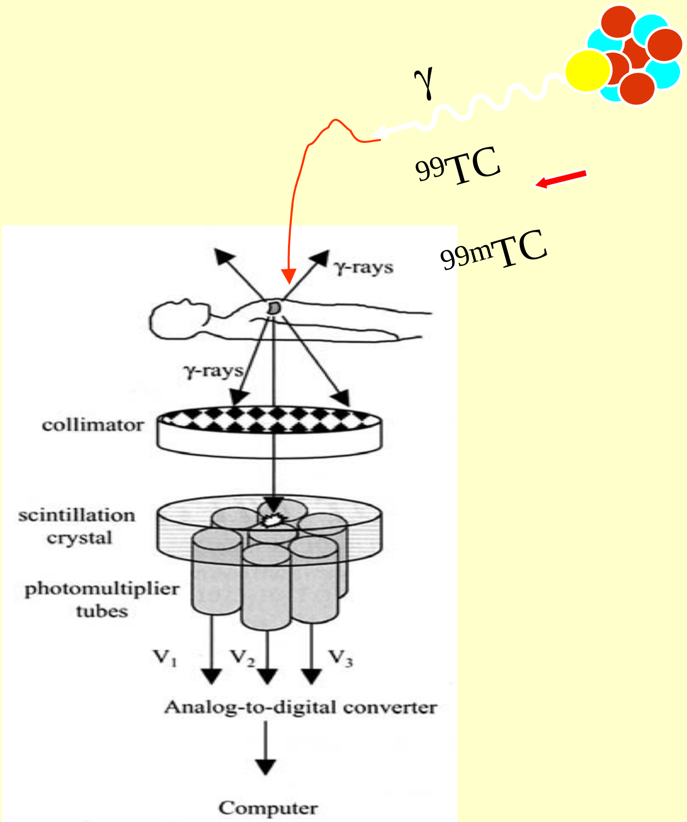
CT: Applications

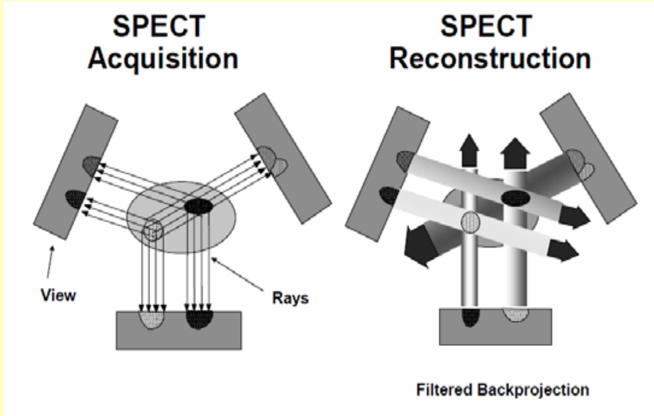
3D Visualization

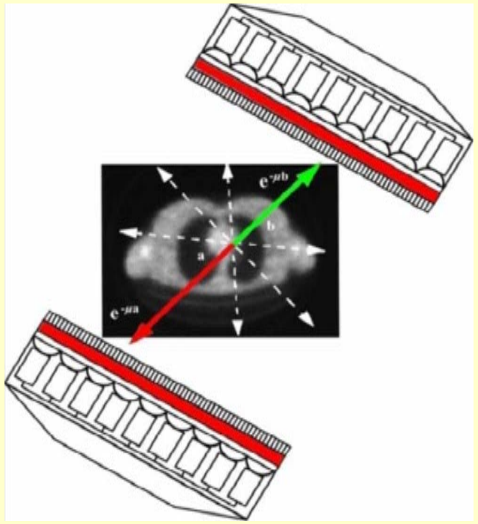


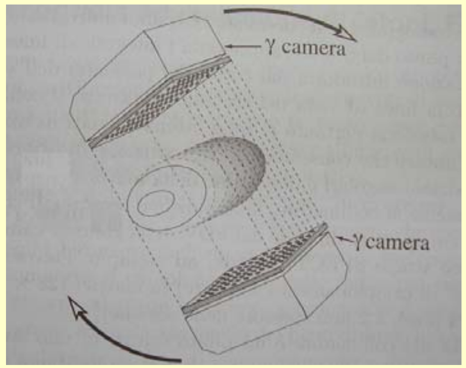
Single Photon Emission Computerized Tomography (SPECT) Imaging

Acquisizione di immagini SPECT

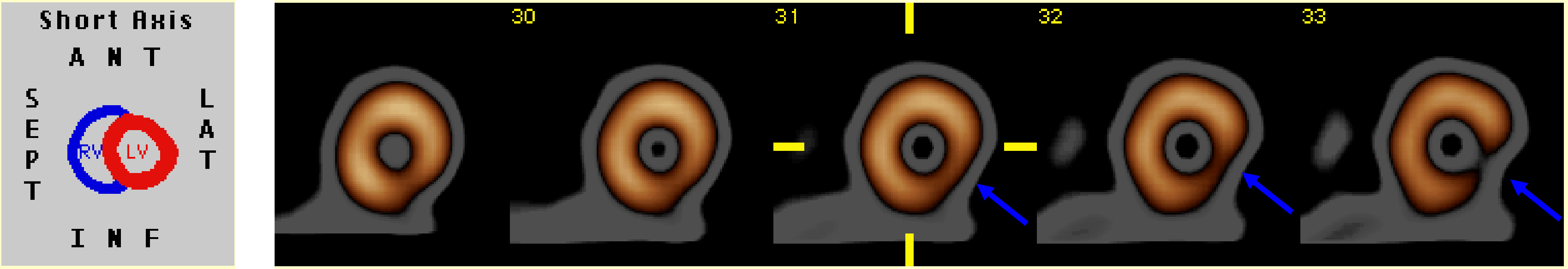


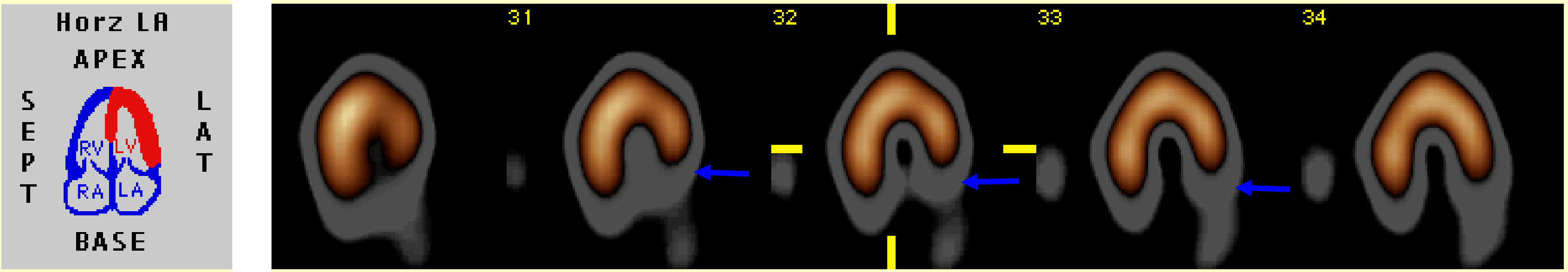




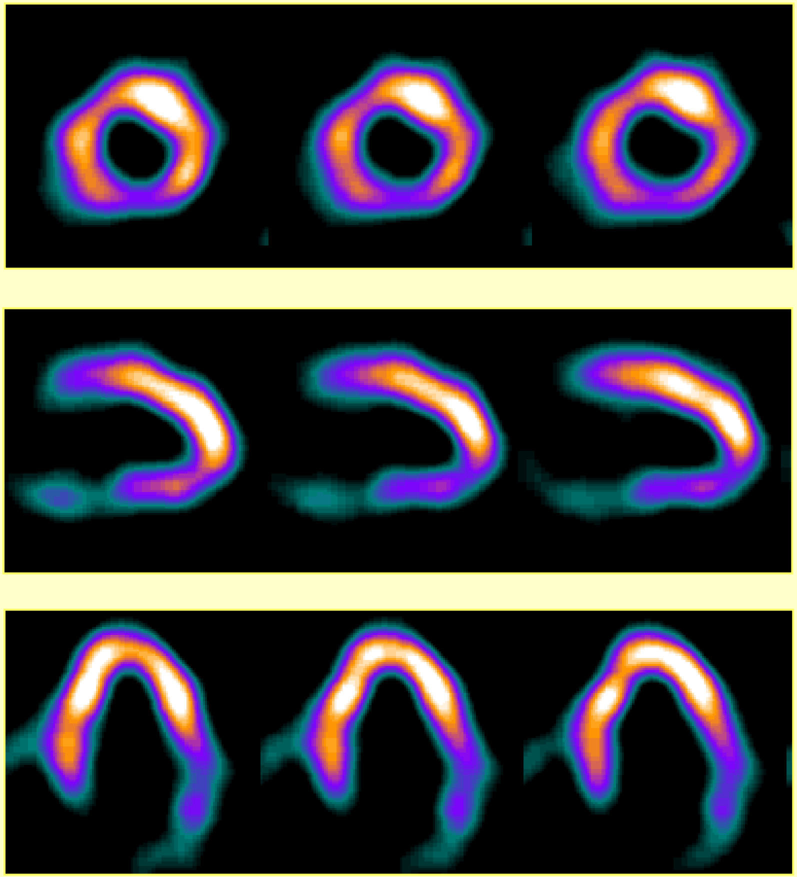


SPECT

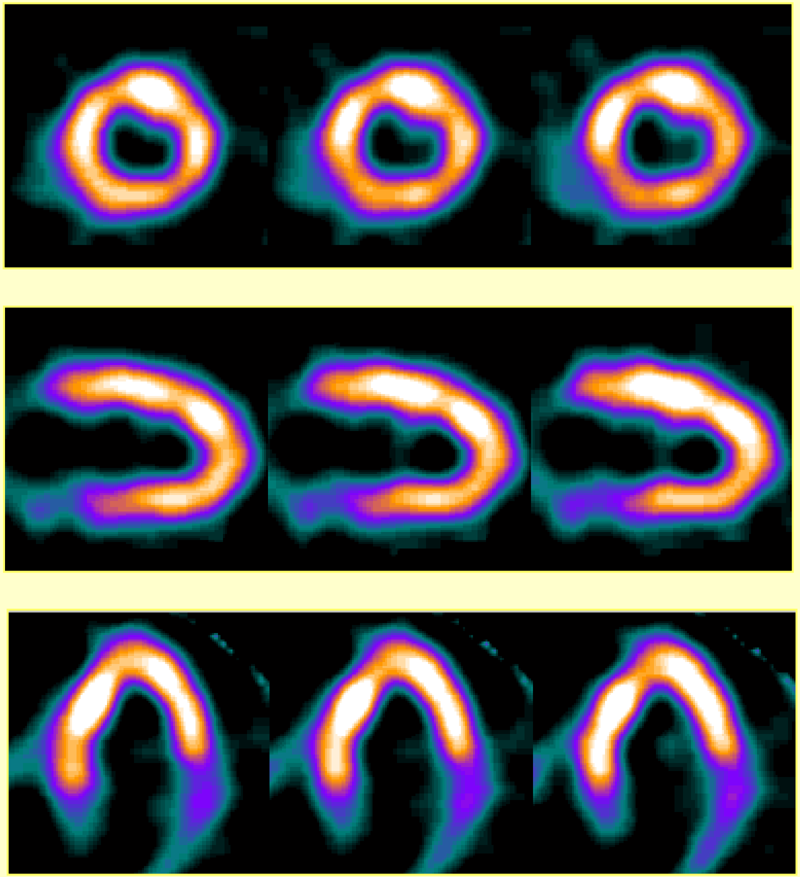

Short Axis
A N T
S E P T
L A T
RV
LV
I N F
30
31
32
33


Horz LA
APEX
S E P T
L A T
RV
LV
RA
LA
BASE
31
32
33
34

SPECT



Dipyridamole

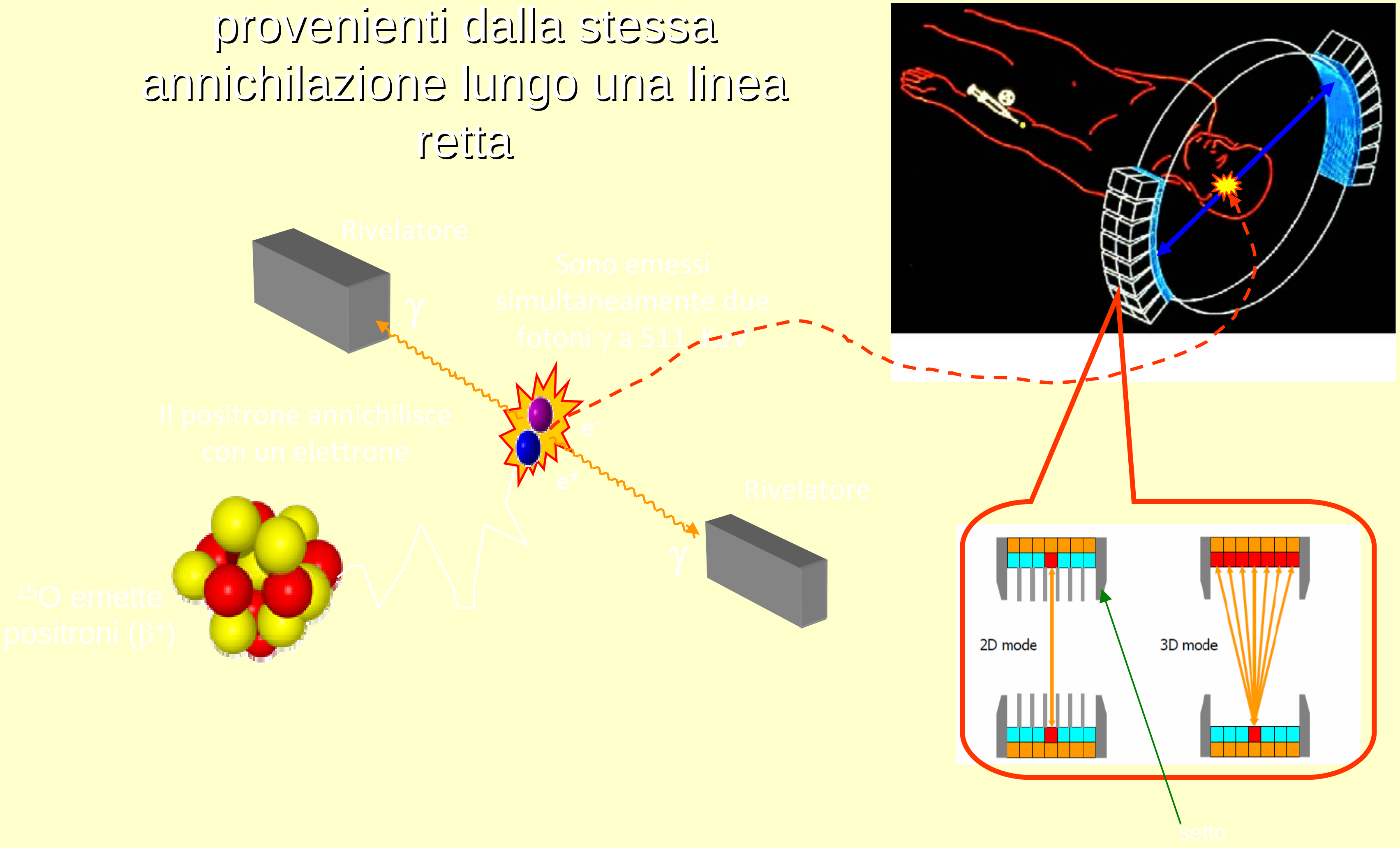


Redistribution

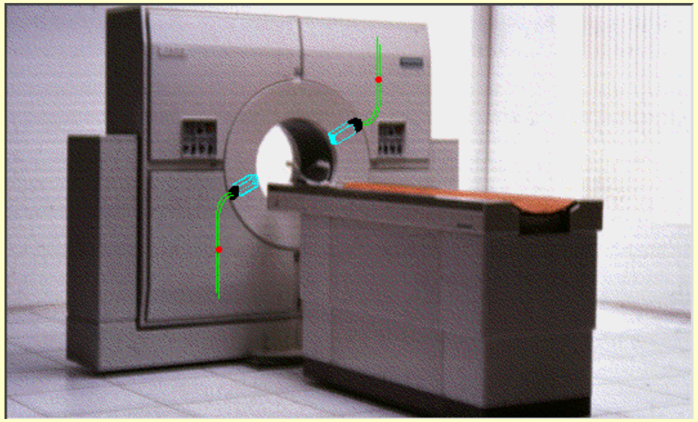
Positron Emission Computerized Tomography (PET) Imaging

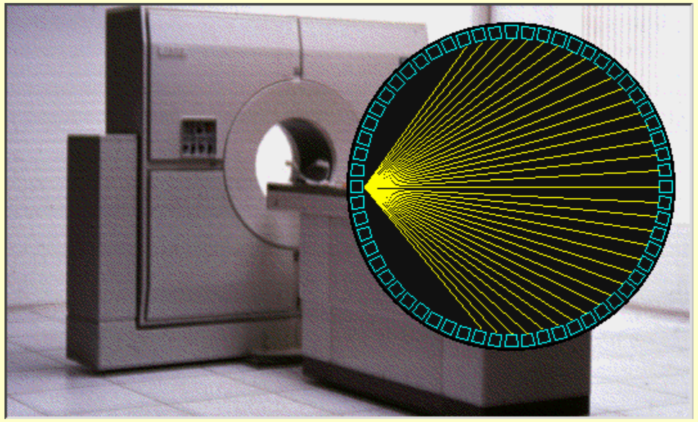
I. Principio fisico della PET

2 fotoni γ in coincidenza a 511 keV, provenienti dalla stessa annichilazione lungo una linea retta

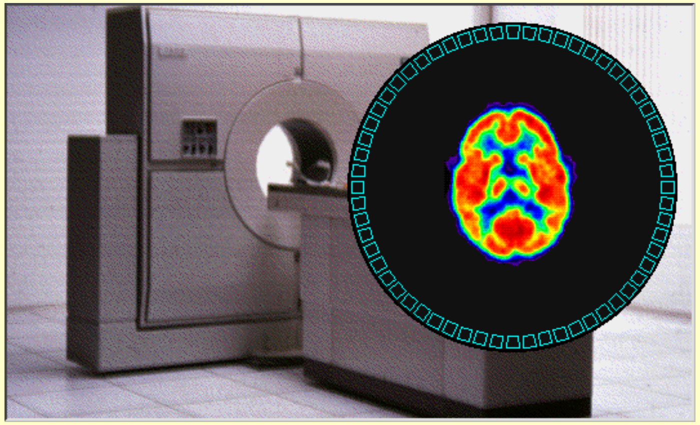


Acquisizione di immagini PET

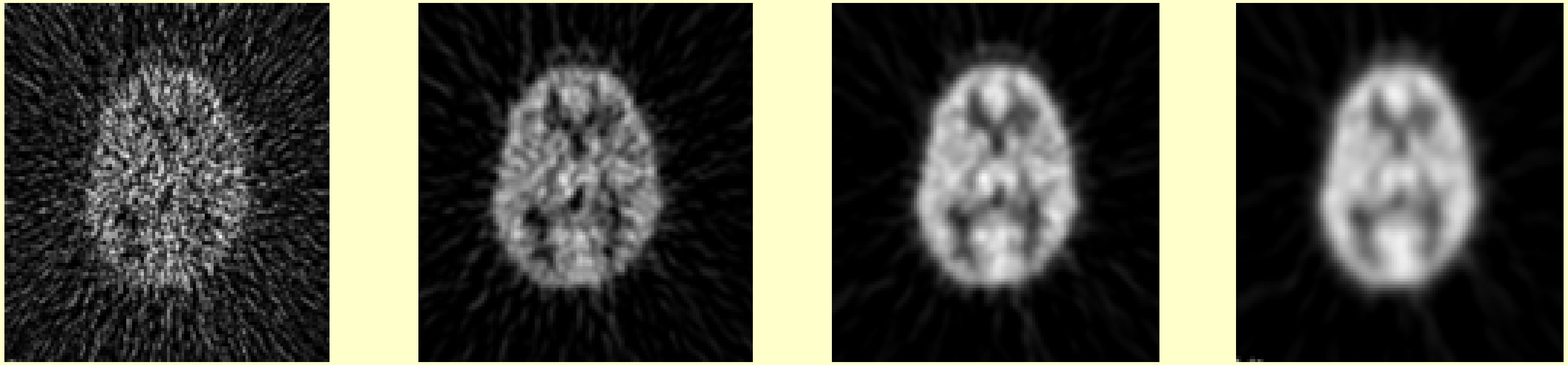




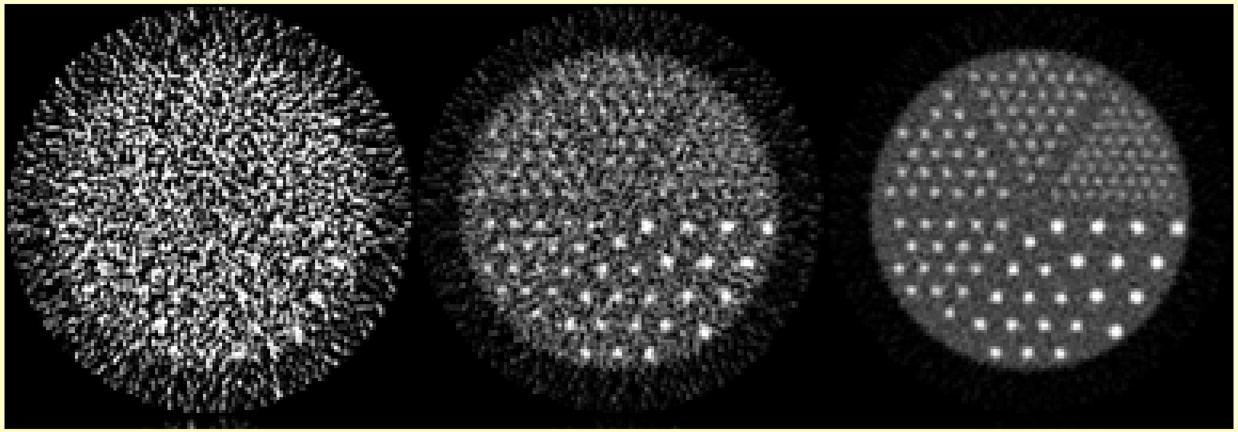
Data acquired by detectors represent the number of counting and the time relevant to counting (synograms).
In order to obtain images, synograms are further processed by means of reconstruction algorithms.



I. Risoluzione spaziale e conteggi

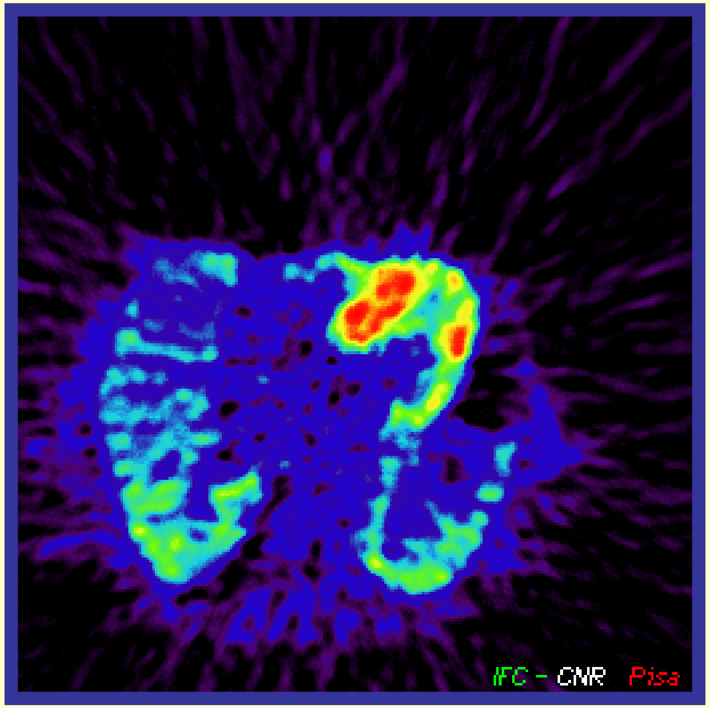


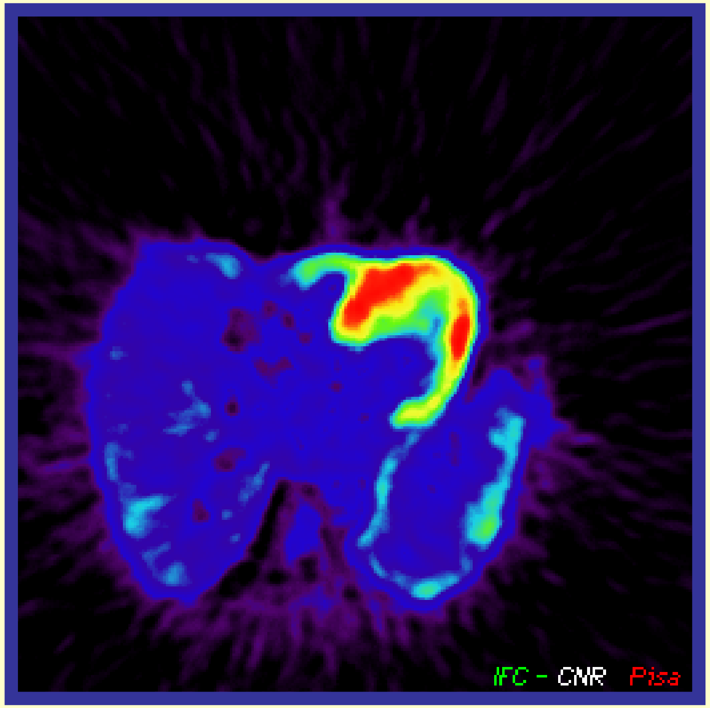
5 mm 6 mm 9 mm 14 mm



10^5 10^6 10^7 conteggi

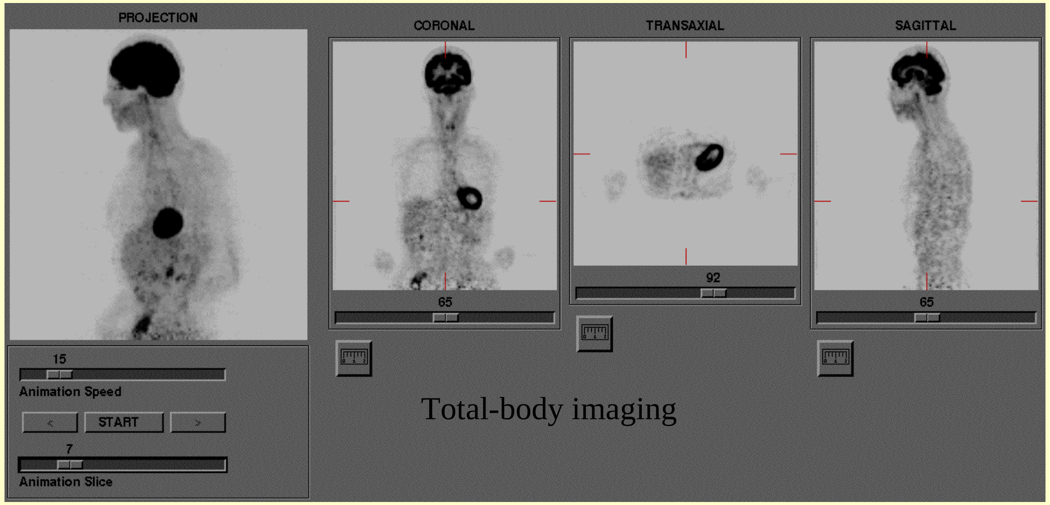
PET: examples



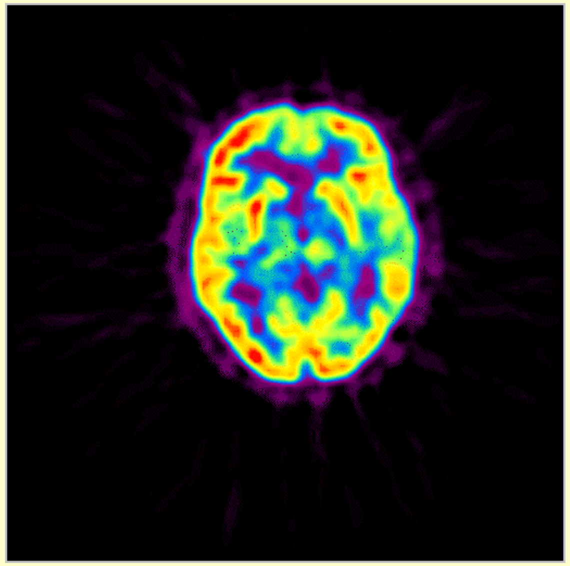


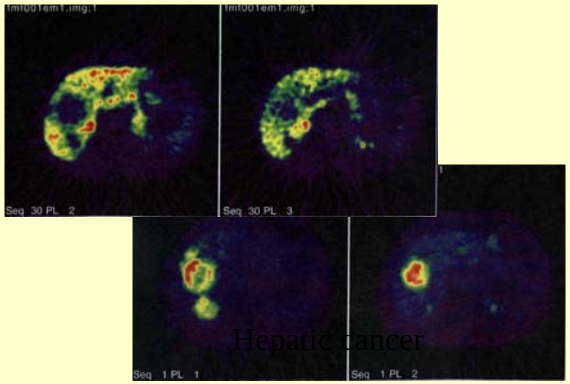
Tracer: $^{13}NH_3$ – ammonia
Usually employed for flux measurements

PET: examples



Total-body imaging

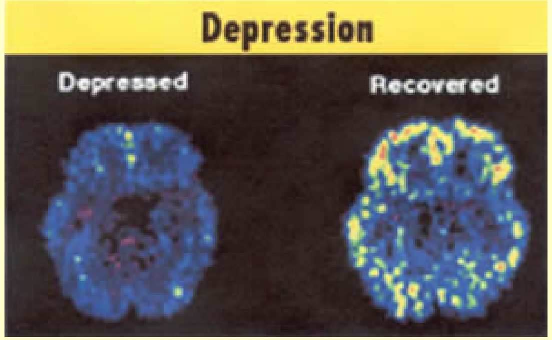


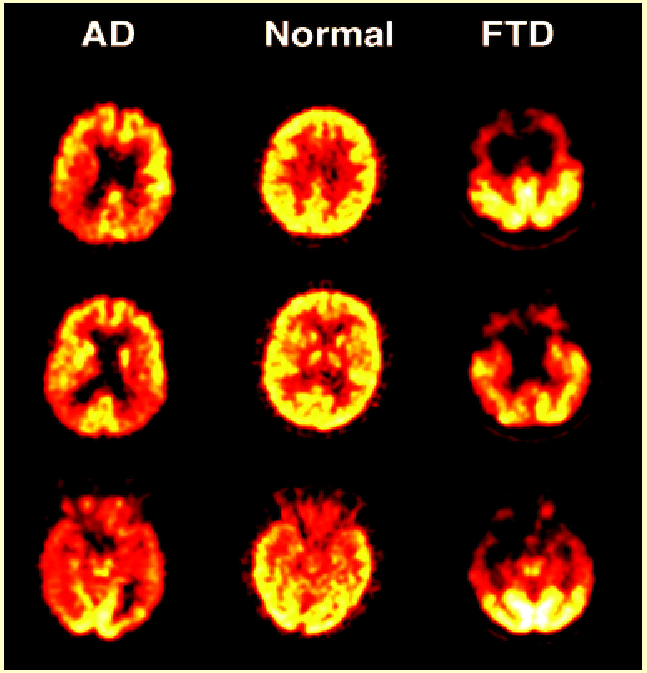


Hepatic cancer

Colon inflammation

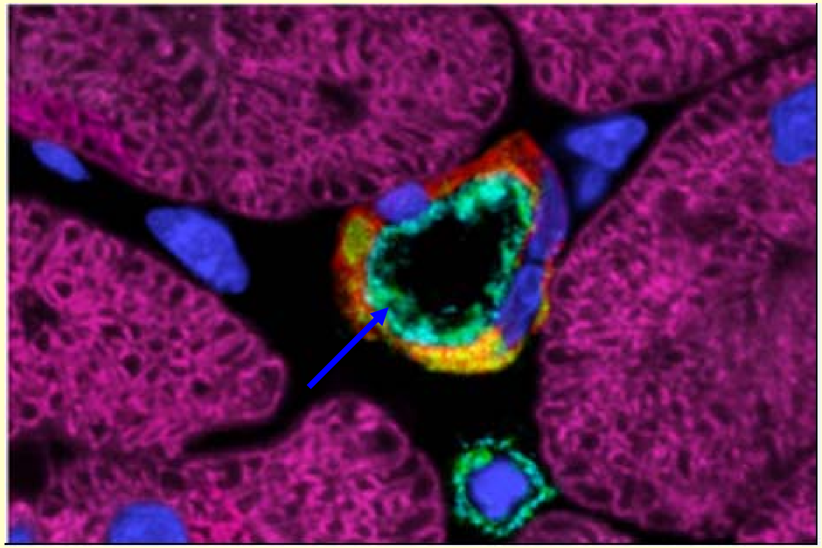
PET: examples





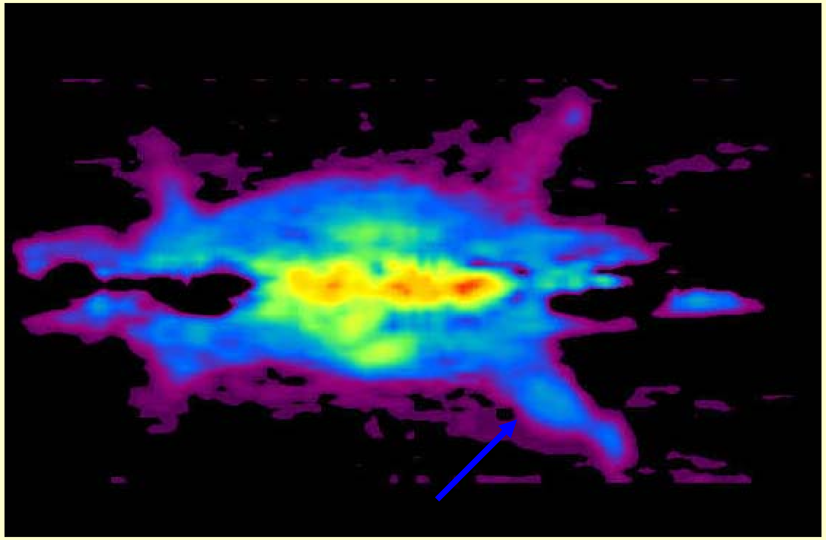
Cerebral glucose metabolism in healthy and pathological state (Depression, Alzheimer Disease, FrontoTemporal Dementia)

Molecular Imaging of Gene Expression
Coronary Endothelium and Muscle



The "present"

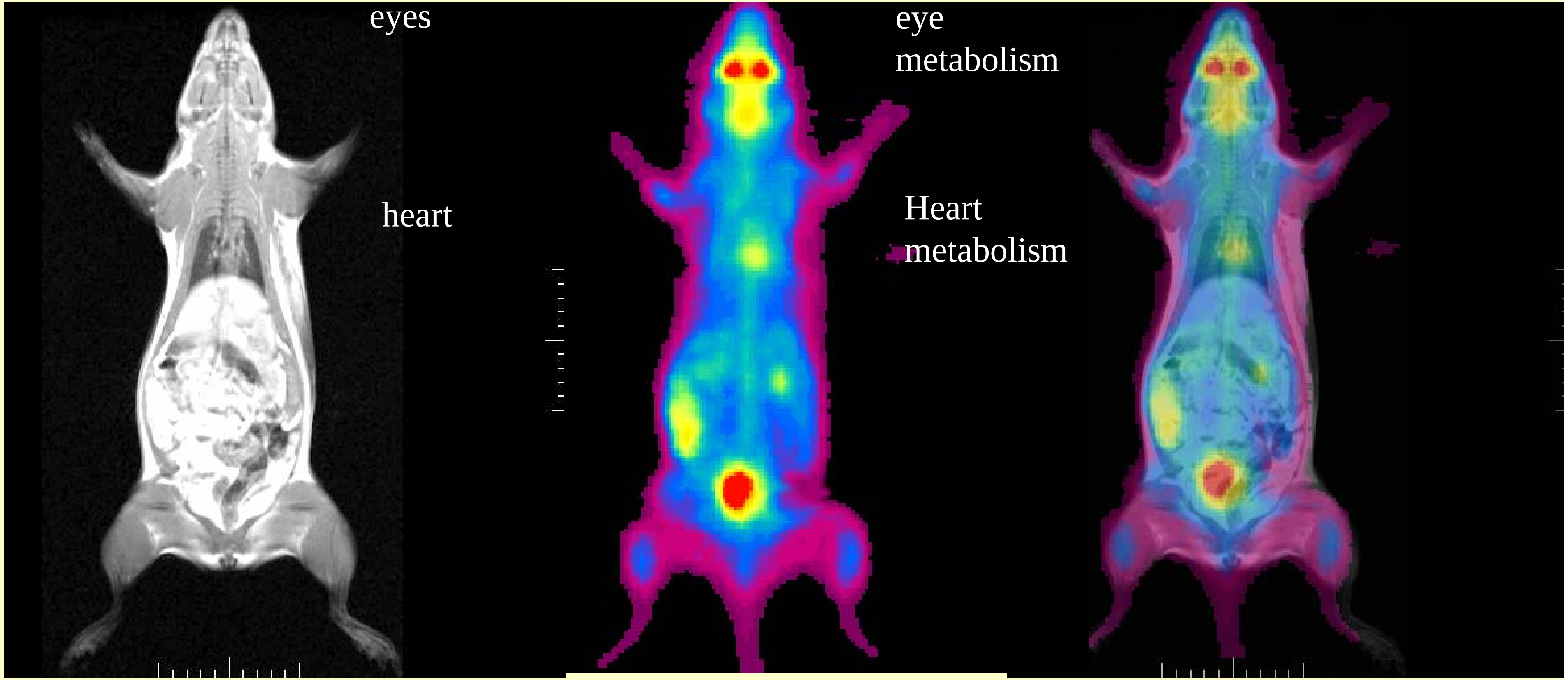
"Immunoistochemistry ex vivo"



The "future"

"PET reporter-gene in vivo "

New trends: microimaging and molecular imaging



MRI Anatomy

and structure

PET physiologic imaging

Combined imaging